STEAM TURBINE TECHNOLOGY

24 – 26 JULY 2019, KUALA LUMPUR, MALAYSIA

TOPICS COVERED

Steam Turbine Components and Systems

Steam Turbine Failure Modes, Inspection, Diagnostic Testing, and Maintenance

Steam Turbine Reliability and Maintainability

Steam Turbine Selection and Applications

Expert Course Faculty Leader

Our expert has more than 32 years of practical engineering experience with Ontario Power Generation as an Engineering Supervisor and Training Manager, has conducted courses and seminars, to more than 4,000 working engineers and professionals who consistently ranked him as "Excellent" or "Very Good". He has also written 5 books for working engineers from which three have been published by McGraw-Hill, New York.
Introduction
This seminar will cover all aspects of steam turbines including design and features of modern turbines, material, rotor balancing, features enhancing the reliability and maintainability of steam turbines, rotor dynamic analysis, Campbell, Goodman and SAFE diagrams, Blade failures: causes and solutions, maintenance and overhaul of steam turbines, and modeling of steam turbines.

This seminar will also cover in detail all the components of these turbines, instrumentation, control systems, governing systems, and selection criteria. The main focus of this seminar will be on the failure modes of steam turbine components, causes and solutions for component failure, maintenance, refurbishment and overhaul, rotor dynamic analysis of steam turbines, and computer simulation of steam turbine rotor dynamics. All possible failure modes of steam turbine components and the maintenance required to prevent them will be discussed in detail. Examples of rotor dynamic analysis, and stability criteria will be covered thoroughly.

This seminar will also provide up-dated information in respect to all the methods used to enhance the availability, reliability, and maintainability of steam turbines, increase the efficiency and longevity of steam turbines, and improve the rotor dynamic stability. This seminar will also cover in detail all steam turbine valves, jacking oil system, turning gear, turbine supervisory system, steam turbine monitoring technology, validation, and verification tests, performance testing of steam turbines and steam turbine codes especially ASME PTC6.

Seminar Outcomes

- **Steam Turbine Components and Systems**: Learn about all components and systems of the various types of steam turbines such as: stationary and rotating blades, casings, rotor, seals, bearings, and lubrication systems

- **Steam Turbine Failure Modes, Inspection, Diagnostic Testing, and Maintenance**: Understand all the failure modes of steam turbine components, causes and solutions of steam turbine component failure, inspection, diagnostic testing, and all maintenance activities required for steam turbines to minimize their operating cost and maximize their efficiency, reliability, and longevity.

- **Steam Turbine Instrumentation and Control Systems**: Learn about the latest instrumentation, control systems, and governing systems of steam turbines

- **Steam Turbine Reliability and Maintainability**: Increase your knowledge about all the methods used to enhance the reliability and maintainability of steam turbines as well as the predictive and preventive maintenance required for steam turbines

- **Steam Turbine Selection and Applications**: Gain a detailed understanding of the selection considerations and applications of steam turbines in steam power plants, co-generation, combined-cycle plants, and drivers for compressors pumps, etc

- **Steam Turbine Valves, Load-Frequency Control, Turbine Bypass Systems, and Steam Turbine Superheater Attemperators**: Gain a thorough understanding of all steam turbine valves, load-frequency control, turbine bypass systems, and steam turbine superheater attemperators

- **Jacking Oil System and Turning Gear**: Learn about the turbine jacking oil system and turning gear operation

- **Turbine Supervisory System**: Gain a thorough understanding of the turbine supervisory system

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- Steam Turbine Monitoring Technology, Validation, and Verification Tests for Power Plants: Learn about steam turbine monitoring technology, validation, and verification tests for power plants
- Steam Turbine Codes: Learn about steam turbine codes including ASME PTC6, DIN Test Code, and International Electrotechnical Commission (IEC) Doc 1, IEC Doc B
- Steam Turbine Rotor Dynamic Analysis, Campbell, Goodman, and SAFE Diagrams: Gain a thorough understanding of steam turbine rotor dynamic analysis, Campbell, Goodman, and SAFE diagrams

Who Should Attend
- Engineers of all disciplines
- Managers
- Technicians
- Maintenance personnel
- Other technical individuals

Training Methodology
The instructor relies on a highly interactive training method to enhance the learning process. This method ensures that all the delegates gain a complete understanding of all the topics covered. The training environment is highly stimulating, challenging, and effective because the participants will learn by case studies which will allow them to apply the material taught to their own organization.

Special Feature
Each delegate will receive a copy of the following materials written by the instructor:
- Excerpt of the relevant chapters from the “POWER GENERATION HANDBOOK” second edition published by McGraw-Hill in 2011 (800 pages)
- Excerpt of the relevant chapters from the “POWER PLANT EQUIPMENT OPERATION AND MAINTENANCE GUIDE” published by McGraw-Hill in 2012 (800 pages)
- STEAM TURBINE TECHNOLOGY MANUAL (includes practical information about steam turbines maintenance, testing, and refurbishment - 500 pages)

This training course has a limited attendance for up to 20 participants only.
Sessions commence at 9am on all days, with short intervals at 10.30am and 3.30pm respectively. Refreshments will be provided in the short intervals. Lunch will be provided at 12:30pm for 1 hour. Sessions will end at 5pm on all days.
Your Expert Faculty

Our expert has been a teacher at University of Toronto and Dalhousie University, Canada for more than 25 years. In addition, he has taught courses and seminars to more than four thousand working engineers and professionals around the world, specifically Europe and North America. He has been consistently ranked as "Excellent" or "Very Good" by the delegates who attended his seminars and lectures.

He wrote 5 books for working engineers from which three have been published by McGraw-Hill, New York. Below is a list of the books authored by him:

5. Industrial Equipment (600 pages), Custom Publishing, University of Toronto, University of Toronto, University of Toronto Custom Publishing (1999).

Furthermore, he has received the following awards:

1. The first "Excellence in Teaching" award offered by PowerEdge Asia Training center, Singapore, December 2016
2. The first "Excellence in Teaching" award offered by the Professional Development Center at University of Toronto (May, 1996).
3. The "Excellence in Teaching Award" in April 2007 offered by TUV Akademie (TUV Akademie is one of the largest Professional Development centre in world, it is based in Germany and the United Arab Emirates, and provides engineering training to engineers and managers across Europe and the Middle East).
4. Awarded graduation "With Distinction" from Dalhousie University when completed Bachelor of Engineering degree (1983).

Our specialist performed research on power generation equipment with Atomic Energy of Canada Limited at their Chalk River and Whiteshell Nuclear Research Laboratories. He also has more than 32 years of practical engineering experience with Ontario Power Generation (OPG - formerly, Ontario Hydro - the largest electric utility in North America). He retired from OPG in November 2016.

While working at Ontario Hydro, he acted as a Training Manager, Engineering Supervisor, System Responsible Engineer and Design Engineer. During the period of time, he worked as a Field Engineer and Design Engineer, he was responsible for the operation, maintenance, diagnostics, and testing of gas turbines, steam turbines, generators, motors, transformers, inverters, valves, pumps, compressors, instrumentation and control systems. Further, his responsibilities included designing, engineering, diagnosing equipment problems and recommending solutions to repair deficiencies and improve system performance, supervising engineers, setting up preventive maintenance programs, writing Operating and Design Manuals, and commissioning new equipment.

Later, he worked as the manager of a section dedicated to providing training for the staff at the power stations. The training provided by him covered in detail the various equipment and systems used in power stations.

Lastly, he was awarded his Bachelor of Engineering Degree "with distinction" from Dalhousie University, Halifax, Nova Scotia, Canada. He also received a Master of Applied Science in Engineering (M.A.Sc.) from the University of Ottawa, Canada. He is also a member of the Association of Professional Engineers in the province of Ontario, Canada.
### 3 Day Course Outline

**Day 1** - Steam Power Plants, Steam Turbine Components, Steam Turbine Auxiliaries, Impulse and Reaction Turbines, Rotor Balancing, Features of Advanced Steam Turbines, and Features Enhancing The Reliability and Maintainability of Steam Turbines, Turbine Control Systems, Turbine Governing System

- Review of thermodynamics principles, efficiency and heat rate
- Steam power plants, steam turbines
- Mechanisms of Energy Conversion in a Steam Turbine, Steam balance considerations
- Steam turbine types (straight noncondensing, automatic extraction noncondensing, automatic extraction condensing)
- Steam turbine controls, Automatic extraction condensing controls,
- Geared and direct-drive steam turbines, modular design concepts
- Turbine components, Rotating and stationary blades
- Steam Turbine casing and major stationary components: casing design, steam admission sections, steam turbine diaphragms and labyrinth packing
- Steam turbine bearings: journal bearings for industrial turbo-machinery, fixed-geometry journal bearing stability, tilted-pad journal bearings, advanced tilting-pad journal bearings, lubrication-starved tilting pad bearings, key design parameters, thrust bearings for turbo-machinery, active magnetic bearings
- Rotors for impulse turbines: long-term operating experiences, pitch diameter and speed, steam turbines, built-up construction, materials of construction for multi-stage steam turbines, solid construction, shaft ends, turbine rotor balance methods, at-speed rotor balancing, advantages and disadvantages of at-speed balancing, balance tolerance
- Rotors for reaction turbines: solid rotors, finite element analysis for steam turbines, materials for solid rotors, welded rotor design, welded rotor materials
- Thrust bearings, labyrinth seals
- Steam turbine blade design: blade material, blade root attachments, types of airfoils and blading capabilities, guide blades for reaction turbines, low-pressure final stage blading. Campbell diagram
- Turbine auxiliaries lube systems, barring or turning gears, trip-throttle or main stop valves, overspeed trip devices, gland seal systems, lube oil purifiers
- Testing of Turbine blades
- Quality Assurance of Turbine Generator Components
- Assembly and testing of turbine components
- Turbine Types, Compound Turbines
- Turbine Control Systems
- Turbine Governing System
- Steam Turbine Maintenance
- Power Station Performance Monitoring
- The Turbine Governing Systems
- Turbine Protective Devices
- Turbine Instrumentation
- Lubrication Systems
- Gland Sealing System


- Steam turbine valves: main stop valves, solid particles erosion of the main stop valve stem, steam chests, improved design of the main stop valve, turbine governing valves, throttle governing of a steam turbine, intercept valves, reheate stop valves, steam turbine drains, steam chests
- Load-frequency control, turbine bypass systems, steam turbine superheater attemperators, atmospheric relief diaphragm
- Jacking Oil System, condensers, vacuum breaker, steam turbine components
- Turbine Supervisory System: parameters monitored by the turbine supervisory system, turbine generator bearing vibrations, HP turbine casing expansion, HP and LP turbine axial differential expansions, shaft axial position, assorted turbine generator temperatures, turbine speed, steam valves position, rotor eccentricity, rate of acceleration, phase angle, thrust collar position, thrust bearing, response of the turbine supervisory system to an exceeded safety limit
- Bearing vibrations, turning gear, purposes of turning gear, turbine gear operation
- Adverse consequences and operating concerns caused by inadequate operation, excessive use of the turning gear, turbine Auxiliary Components

**Day 3** - Features of Advanced Steam Turbines
- Constant and sliding pressure operation of steam turbines
- Frequently Asked Questions about Turbine-Generator Balancing, Vibration Analysis and Maintenance
- Steam turbine rotor failures: causes and solutions: rotor rubs, blade rubs causing bending, rotor and casing misalignment, bearing problems, alignment of diaphragms, achieving precise alignment, rotor imbalance, corrosion causing rotor imbalance, failures due to poor maintenance, casing problems
- Steam Turbine Deposit, Erosion, and Corrosion
- Features Enhancing The Reliability and Maintainability of Steam Turbines: steam turbine design, measures of reliability, availability, and maintainability, design attributes enhancing reliability, overall mechanical design approach, modern steam turbine design features, design attributes enhancing maintainability, maintainability features, maintenance recommendations, cost/benefit analysis of high reliability, maintainability, availability, and maintenance performance, reliability, availability, and maintainability value calculation
Steam turbine monitoring technology, validation, and verification tests for power plants: performance testing of steam turbines, ASME PTC6 Steam Turbines, DIN Test Code, International Electrotechnical Commission (IEC) Doc 1, IEC Doc B

- Enthalpy drop test, ASME PTC6 Code, frequency of turbine testing, typical turbine efficiency, errors in measurements, effect of loading upon turbine efficiency, temperature and pressure at an IP turbine stage, volumetric flow rate through the turbine
- Effect of deterioration of cylinder efficiency on heat rate, effect of a change in IP turbine efficiency on heat rate, effect of surface smoothness of turbine blades on heat rate, effect of blade friction on turbine performance, effect of blade friction on heat rate, variation of heat rate for various size machines and different degrees of roughness
- Turbine pressure survey, basic turbine pressure survey diagram, effect of load change, relationship between stage pressure and output, variation of stage pressure with loading, effect of a range of loadings on pressure survey diagrams, wear throughout the turbine, effect of internal wear on pressure survey diagrams
- Steam turbine blade seals, restriction in the steam flow, effect of internal restriction to flow on pressure survey diagrams, LP cylinder
- Feedwater heaters, Effect of feedwater heaters out of service on pressure survey diagram, silica deposition, silica deposition on steam turbine blades, effect of silica in boiler feedwater, scale build-up inside the boiler tube walls, turbine blade contamination, effect of silica deposition on LP turbine inlet pressure, pressure increase at the inlet to the LP turbine, sources of contamination
- Shaft glands, steam turbine gland sealing, typical turbine gland sealing system, gland steam condenser, damage to turbine glands due to high vibration
- Effect on heat rate of using reheater spray water
- Condensers and backpressure: increase in power output due to a drop in back pressure, condenser liquid ring vacuum pump, air ejector, determination of the location of the condenser leak, Leybold leak detector, joints on the LP, bled steam pipes, identifying condenser tube leaks, on-load tube cleaning, solution to reduction in heat transfer across the condenser tubes, phosphate scale formation
- Feedwater heating: steam power plant cycle with feed heating, thermal improvement due to feedwater heating, types of feedwater heaters, deaerator and its storage tank, arrangement of feedwater heaters
- Turbine boiler feed pump

Day 3 - Steam Turbine Rotor Dynamic Analysis, Campbell, Goodman, and SAFE Diagrams, Advanced Steam Turbine Design, Materials and Coatings, Steam Turbine Blade Failures, Causes and Solutions, Maintenance and Overhaul of Steam Turbines

- Steam turbine rotor dynamic technology: rotor model, dynamic stiffness, effects of damping on critical speed prediction, bearing-related developments, refinements, bearing support considerations, foundations, impedance, partial arc forces, design procedure, rotor response, instability mechanisms, subsynchronous vibration, service examples, labyrinth and cover seal forces, rotor stability criteria, experimental verification
- Campbell, Goodman, and SAFE Diagrams for Steam Turbine Blades: Goodman diagram, Goodman-Soderberg diagram, Campbell diagram, exciting frequencies, SAFE diagram-evaluation tool for packeted bladed disk assembly, definition of resonance, mode shape, fluctuating forces, SAFE diagram for bladed disk assembly, mode shapes of a packeted bladed disk, interference diagram beyond N/2 limit, explaining published data by using SAFE diagram
- Frequency Evaluation of Steam Turbine Rotors: natural frequency and mode shape, vibratory forces, resonance, Campbell diagram, SAFE diagram,
- Reaction vs impulse type steam turbines: impulse and reaction turbines compared, efficiency, design, impulse type, reaction type, critical speed, blading, vibration, control stage, full-admission stages, blade damage, blade clearances, erosion, axial thrust, maintenance, design features of modern reaction turbines, deposit formation and turbine water washing
- Shortcut graphical methods of turbine selection: estimating steam rates, steam turbine selection procedure, examples of steam turbine selection, quick reference information to estimate steam rates of multivalve multistage steam turbines
- Elliott shortcut selection method for multivalve, multistage steam turbines: approximate steam rates, stage performance determination, examples of steam turbine selection process, extraction turbine performance
- Rerates, Upgrades, and Modifications of Steam Turbines: performance and efficiency upgrade, brush seals and labyrinth seals, wavy face dry seals, replacing carbon rings with wavy dry seals, design goals and available technologies, seal design specifics, installation of seals, installation sequence, cost vs. benefit analysis, buckets, reliability upgrade, electronic controls, monitoring systems, life extension, modification and reappraisal, casing, flange sizing, nozzle ring capacity, steam path analysis, rotor blade loading, thrust bearing loading, governor valve capacity, rotor, shaft and reliability assessment, speed range changes, auxiliary equipment review, oil mist lubrication for general-purpose steam turbines, wet sump (purge mist) vs. dry sump (pure mist) application, control and application of oil mist, header temperature and header size, experience and conducting comments, problem solving
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- Advanced Ultra Supercritical Steam Turbine Materials: design of ultra supercritical steam turbines, steam oxidation, creep resistance, rupture ductility, nickel-based alloys, creep curves of different steam turbine materials, yield strength of different steam turbine materials, temperature capabilities of nickel-based superalloys for high pressure and intermediate pressure steam turbines, composition of various high-temperature superalloys considered for advanced ultra supercritical steam turbines, advanced ultra supercritical turbine designs using nickel-based superalloys

- Advanced Steam Turbine Design, Materials, and Coatings: materials used in advanced steam turbines, design and materials used in high pressure steam turbine rotors, intermediate pressure rotors, steam turbine casings, and bolting, rotor materials — advanced processing of current alloys, nickel-base rotors, welding of udimet 720 and Inconel 617, isothermally forged nickel-base rotors, high temperature disc materials, rotor blade materials — advanced processing of current alloys, erosion resistant coatings, casing materials and large scale nickel castings, bolting — high temperatures bolt alloy, high strength pipe materials, efficiency improvement of steam turbines, characteristics of 50 and 60-inch last stage blades, fluid performance design, development of supersonic turbine blades, structural reliability design, vibration design, conclusions

- Steam Turbine Blade Failures, Causes and Solutions, failure investigation
- Steam turbine risk assessment — a tool for optimizing inspection and overhauls of steam turbines: outage planning factors,
- Maintenance and Overhaul of Steam Turbines: steam turbine component characteristics, failure mechanisms, arrangements and applications, monitoring, operations, maintenance, and training infrastructure, steam turbine availability and failure experience, scheduled maintenance and overhaul practices, approaches/methodologies/criteria for establishing longer time intervals between major overhauls, issues with new steam turbine technologies and applications

- Methods of Strategic Oil Flushing Program; high-velocity turbine lube oil flushing using pulse-induced wave technology
- Turbine Blasting
- Steam Turbine Rotor Dynamic Analysis: comparative analysis of different components of rotor dynamic stability, Bode plot of rotor dynamic analysis
- Steam Turbine Rotor Dynamics and Vibration Diagnostics
- Modeling of Steam Turbine Rotor Dynamics: understanding rotor dynamics, solid model rotor dynamics, modeling methods, results
- Advanced Water Treatment Technology: reverse osmosis systems, nanofiltration, ultrafiltration and microfiltration, electrodeionization (EDI), activated carbon filtration, multimedia filtration, ozonation systems, ultraviolet irradiation, steam turbine water treatment
- Glossary of turbo-machinery and related equipment terms
- Computer Simulation of Steam Turbine Rotor Dynamics: rotor equations, examples of computer simulation of rotor dynamic analysis
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